

# The biology and conservation status of Gough Bunting *Rowettia goughensis*

by Peter G. Ryan & Richard J. Cuthbert

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Gough Bunting *Rowettia goughensis* is a large (60 g) finch endemic to Gough Island in the central South Atlantic Ocean. It evolved from South American finches and is closely related to *Nesospiza* buntings from Tristan da Cunha (Ryan *et al.* 2007), but also bears a striking resemblance to *Melanodera*, a genus of finches found in southern South America and the Falklands (Lowe 1923). Gough Bunting was initially described as two species: *Nesospiza goughensis* for birds in the plain olive adult plumage and *N. jessiae* for birds in the distinctive, streaky juvenile plumage (Clarke 1904, 1905). Clarke assumed that the transitional immature plumage was the winter plumage of *N. goughensis*. Lowe (1923) corrected this misconception and, given its unusually long bill and apparent affinity to *Melanodera*, placed the species in its own genus.

Relatively little has been published on the biology of Gough Bunting (Collar & Stuart 1984) and its nest and eggs were described as recently as 1979 (Voisin 1979). The species is currently listed as Vulnerable because it is confined to a single, small island (BirdLife

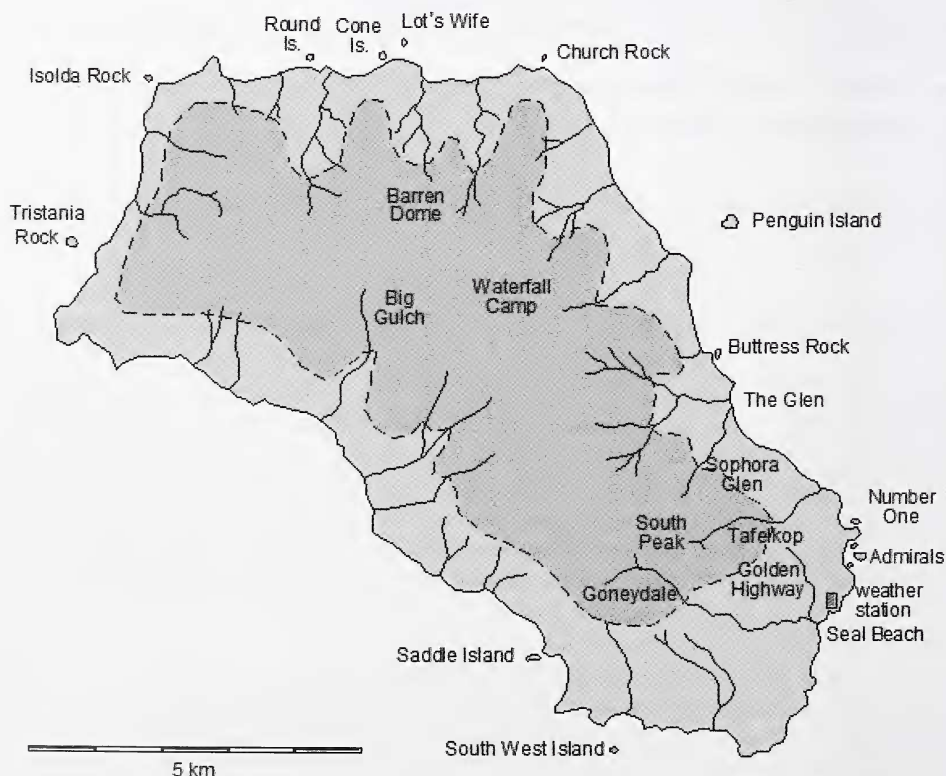


Figure 1. Gough Island, showing the locations mentioned in the text, as well as the large offshore stacks. The dark shaded area is the approximate extent of highland habitats (wet heath, *Sphagnum* bogs and feldmark).

International 2004), and is at risk from the accidental introduction of predators such as rats *Rattus* spp. or cats *Felis catus*. Tristan Bunting *Nesospiza acunhae* became extinct on the main island of Tristan da Cunha barely 50 years after the island was settled by humans, probably as a result of the introduction of House Mice *Mus musculus* and feral cats (Ryan in press). They apparently were extinct prior to the arrival of Black Rats *Rattus rattus*, which were only introduced to Tristan in 1882 (Hagen 1952).

Recently, concern has been raised about the status of Gough Bunting, given probable predation of eggs and chicks by introduced House Mice (Cuthbert & Hilton 2004). Impacts are probably greater in the lowlands, where mouse densities are greater, resulting in most buntings being confined to highlands (Cuthbert & Hilton 2004). The few nests found at low elevations in 2000/01 were confined to coastal cliffs, where the risk of mouse predation presumably is reduced. The higher predation rate of artificial nests in lowland areas than in highland areas was used to support this hypothesis (Cuthbert & Hilton 2004). If mice have impacted Gough Bunting, it is important to test whether a new equilibrium has been reached after more than a century of interaction, or whether the bunting population continues to decrease.

Here, we present recent observations on the distribution and abundance of Gough Bunting, suggesting that the population has decreased significantly, and continues to decline. We estimate the abundance of invertebrate prey in different habitats to assess whether competition or predation is the main driver of bunting population decreases. We also summarise information on the bird's plumage development and morphology, foraging behaviour, breeding biology and movements.

## Review of status

Discovered by the Portuguese in 1505, the position of Gough Island was incorrectly recorded, and it was only rediscovered in 1731. The island's inhospitable coast and lack of sheltered anchorages resulted in few landings until the start of commercial sealing in the early 19th century, when mice were introduced accidentally (Wace & Holdgate 1976). The first records of the terrestrial biota were made by George Comer, a sealer who spent five months based at The Glen in 1888–89. He reported that buntings were 'very common' (Verrill 1895: 463). At least five were collected close to the shoreline in The Glen during a four-hour visit by naturalists from the *Scotia* in April 1904 (Clarke 1905), and Wilkins (1923) collected 28 specimens during a four-day visit in May–June 1922. Wilkins reported that buntings occurred in 'considerable numbers' at The Glen, becoming 'not quite so plentiful' at higher elevations (p. 505). He usually found them foraging in groups of 5–7 birds, with roughly equal numbers of adults and juveniles.

Gough Bunting was still quite common in the 1950s to 1970s. The Gough Scientific Expedition estimated a total population of 2,000 birds in 1956, when they were common in The Glen (Holdgate 1957, 1958). Based on their experience in 1956, Wace & Holdgate (1976) reported buntings to be more common than moorhens. In May 1968, Clive Elliott found buntings to be 'numerous' along the beach at The Glen (Elliott 1969); he observed 16 buntings (50% in juvenile or immature plumage) at The Glen during two days ashore (Elliott 1970). In 1977, Voisin (1979) reported the bunting to be 'fairly abundant', and in 1980 Clancey (1981) judged it to be 'not uncommon' around the weather station, occurring in thickets of island tree *Phylica arborea* as well as coastal tussock. By comparison, Richardson (1984) found the bunting to be not particularly common on a five-day visit in October–November 1974. He proposed a total population as low as 200 pairs, based on an estimate of 4 pairs/km<sup>2</sup>. His assessment may have been influenced by his experience of



*Nesospiza* buntings at Inaccessible and Nightingale Islands in the Tristan group, which occur at much higher densities than Gough Buntings (up to 20 pairs/ha<sup>-1</sup> in coastal tussock on Inaccessible; PGR unpubl.). Surprisingly, Richardson (1984) did not record buntings above 300 m elevation, although it is unclear to what extent he explored upland areas.

Subsequent to 1980, there are few published data on the abundance and distribution of the bunting. BirdLife International (2000) gave an estimate of 1,500 pairs, based on density estimates made by territory mapping in 1990–91 (this paper). This was revised to 400–500 pairs (BirdLife International 2004) based on Cuthbert & Sommer’s (2004) estimate of 23 pairs/km<sup>2</sup> in wet heath vegetation at Gonydale, extrapolated across 15.2 km<sup>2</sup> of wet heath, and 1.7 pairs/km<sup>2</sup> along 42 km of coastal cliffs. Cuthbert & Sommer (2004) ignored pairs nesting in other habitat types. However, their estimate of density in the highlands was in error, being incorrectly calculated from a mean nearest-neighbour distance of 118 m between nests to provide an estimated density of 23 pairs/km<sup>2</sup>. The correct figure should be roughly 90 pairs/km<sup>2</sup> (Cuthbert & Sommer 2004). Using inter-nest distances is biased, however, because nests are clustered along stream banks and gulleys. A better estimate is obtained by dividing the number of nests (13) by the area of Gonydale (c.65–85 ha), which gives roughly 15–20 pairs/km<sup>2</sup> in upland wet heath vegetation.



Figure 2. Gough Buntings *Rowettia goughensis*, showing the three main plumages exhibited in spring: a) a streaky juvenile which is presumably one year old, b) an immature female in transitional plumage (males have a black bib in this plumage), and c) an adult male in plain olive plumage, showing a relatively large and intense dark face mask and bib (P. G. Ryan)

## Study area and methods

Gough (40°S, 10°W) is a remote, cool temperate island of 65 km<sup>2</sup> lying 380 km south-southeast of Tristan da Cunha. It is mountainous, with convex cliffs along the west coast, gently sloping lowlands in the south, and deeply incised valleys along the north and east coasts, of which The Glen is the largest. The island has five main vegetation types (Wace 1961). Tussock grassland, dominated by *Spartina arundinacea* and *Paridochloa flabellata*, occurs up to 300 m on coastal cliffs, mainly along the west coast. Fern bush is a diverse plant community found in coastal lowlands, locally to c.450 m. Characteristic species include the island tree *Phyllica arborea* and bogfern *Blechnum palmiforme*. At higher elevations, fern bush grades into wet heath, a transitional vegetation type with large numbers of grasses, sedges and mosses. Areas of impeded drainage in the highlands support *Sphagnum* bogs, whereas the highest peaks and exposed ridges have short feldmark vegetation (Ryan 2007). In addition to the main island, there are several offshore stacks (Fig. 1). The largest and most isolated stack is Penguin Island, a 2.2-ha vegetated stack 750 m off the east coast. The only other large stack with extensive vegetation is Saddle Island (c.0.8 ha), 250 m off the west coast.

Gough Buntings were caught with long-handled scoop nets by PGR during 3–4 week visits to the South African weather station in the spring (September–October) of 1990, 1991, 1999, 2001, 2006 and 2007. All birds were weighed, measured and banded, with most being given unique colour band combinations. The following measurements were taken: mass to the nearest 0.2 g, flattened wing chord and tail to the nearest 1 mm, tarsus to the nearest 0.2 mm, and total head, culmen length and bill depth at the base to the nearest 0.1 mm. Adults and immatures could be sexed on the basis of plumage characters (males have larger masks and bibs), behaviour and vocalisations. However, streaky juveniles could not be sexed reliably. Some additional birds, mainly fledglings, were colour banded during the summers of 2000/01 by RJC and 2004/05 by Marie-Hélène Burle. The age and sex ratios of banded birds are not considered to be representative of the population as a whole, because juveniles are easier to catch than older birds, and the difficulty of catching adult males and females varies during the breeding season. Bunting movements were estimated from re-sightings of individually colour-marked birds.

In 1990, 1991 and 2007, territories were mapped in the South Peak–Tafelkop region (c.30 ha) using individually colour-marked birds to determine territory boundaries. Approximate numbers of pairs also were counted in several other areas, based on observations of singing males and nest searches. Density estimates were extrapolated across the island, assuming 25 km<sup>2</sup> of suitable habitat above 450 m (wet heath and sheltered slopes). In September 2007, all buntings encountered in upland areas were counted during a survey of Tristan Albatross *Diomedea dabbenena* chicks, and classified in three age classes (Fig. 2): streaky juveniles (birds 1–2 years old), immatures in transitional plumage (presumably 2–3 years old), and adults (plain olive plumage, 3+ years old). The proportion of juveniles in different areas was then related to the breeding success of Tristan Albatrosses in these areas (Cuthbert *et al.* 2004, Wanless 2007), to test whether areas with high mouse predation on albatross chicks have fewer juvenile buntings. We also visited Penguin Island to assess the numbers of buntings there. Penguin Island is very seldom visited, and is apparently free of introduced mice; searches for droppings and burrows (readily found on the main island) revealed no sign of their presence.

Bunting foraging behaviour and diet were studied by direct observation during all visits to Gough. Most prey items were small invertebrates that could not be identified accurately, but the foraging technique and the substratum from which they were obtained



TABLE 1

Numbers of pairs of Gough Buntings *Rowettia goughensis* holding territories in different areas of Gough Island in 1990/91 and 2007. Numbers in parentheses include pairs not in adult plumage.

Region	Habitat	Approximate area	1990/91	2007
South Peak–Tafelkop	wet heath	30 ha	10	4 (7)
Waterfall Camp	wet heath	10 ha	5	1 (2)
Golden Highway cliffs	fern bush	15 ha	1 (2)	0
Seal Beach to Admirals	coastal tussock	5 ha	2 (3)	2
The Glen	tussock and fern bush	4 ha	5	1
Total		66 ha	23 (25)	8 (12)

were recorded. In addition, in 1990 bunting faeces and the stomach contents of one bird killed accidentally in a mouse trap at Waterfall Camp were examined under a dissecting microscope. To assess the abundance of invertebrate prey in different habitats, we placed pitfall traps in coastal tussock, fern bush and wet heath in December 2000. Two sites were selected in each habitat, with 20 traps deployed at each site. The traps were emptied after six days in coastal tussock and fern bush, and after ten days in wet heath. The numbers of invertebrates were counted, with no attempt to correct for the different exposure periods.

The locations and contents of all bunting nests found were described. Nests were readily located during the incubation and brood stage, because males regularly feed females at the nest (see Results), with females uttering a distinctive begging call. Not all nests on cliffs could be accessed, and thus sample sizes for nest sites are larger than those for other nest parameters. Nest dimensions were measured to the nearest 5 mm and eggs to the nearest 0.1 mm. The behaviour of breeding buntings was observed during nest observations lasting 80 hours at 15 nests in 1990 and 2000. The male and female of each breeding pair could be distinguished in the field based on plumage and vocal differences.

## Results

A total of 117 Gough Buntings was banded on Gough between 1990 and 2007: 106 in the highlands, nine in coastal tussock around the weather station between Seal Beach and the Admirals, and two at The Glen. Most were full grown, but 27 were banded as chicks or fledglings, all in the highlands. Fifteen (nine adults, one immature, three juveniles and two fledglings) were re-sighted at least six months after being banded. Most were seen 1–2 years later, but two (one banded as an adult male and one as a fledgling) were seen seven years later. Median displacement was 0 m (mean 230 m). The longest movements were 1.2 km, made by a juvenile after seven months, and 0.8 km, by a fledgling in just less than two years. All other movements were <500 m, and not readily distinguished from no movement, given that buntings were seen to fly at least 500 m on occasions during intraspecific aerial chases. Adults usually remained in their territories, but occasionally chased other buntings over adjacent territories. Juveniles tended to be more mobile, sometimes being chased at least 800 m by two or more pairs of territory holders. Occasional juveniles were observed making long-distance movements of their own volition; one flew c.1 km from the upper reaches of Sophora Glen south beyond Tafelkop, travelling high over at least three territories.

All birds banded in adult plumage retained this plumage in subsequent sightings. The only bird banded in transitional immature plumage had moulted into adult plumage a year later. Two birds banded in streaky juvenile plumage in spring, at least one year after fledging, had moulted into immature plumage a year later. Another juvenile, banded in March, still retained juvenile plumage in October. However, a fledgling seen almost two years later

TABLE 2

Mass (g) and morphometrics (mm) of Gough Buntings *Rowettia goughensis*. Juveniles cannot be sexed reliably on external characters.

Character	Male (n=20) mean ± SD (range)	Female (n=27) mean ± SD (range)	Juveniles (n=40) mean ± SD (range)
Mass	60.1 ± 3.4 (53.0–66.1)	57.2 ± 3.9 (50.2–67.8)	58.1 ± 3.5 (48.0–64.7)
Wing	106.5 ± 1.1 (104–108)	103.0 ± 1.6 (100–106)	105.2 ± 2.3 (99–109)
Tail	86.9 ± 4.0 (76–91)	85.5 ± 4.4 (76–92)	82.3 ± 4.5 (71–92)
Tarsus	31.2 ± 1.0 (29.2–32.8)	30.9 ± 0.8 (29.2–32.6)	31.3 ± 1.0 (28.8–33.0)
Total head	42.9 ± 0.6 (42.0–44.2)	42.6 ± 0.6 (41.5–43.9)	42.7 ± 0.7 (41.1–44.2)
Culmen	19.0 ± 0.6 (18.0–20.0)	18.8 ± 0.5 (18.0–20.1)	18.8 ± 0.5 (17.9–19.9)
Bill depth	8.7 ± 0.2 (8.2–9.0)	8.6 ± 0.2 (8.3–9.0)	8.7 ± 0.2 (8.1–9.2)

was still in streaky juvenile plumage, indicating that at least some retain this plumage for two years.

*Abundance and distribution.*—Gough Buntings were observed throughout the island, but were rare in fern bush, and most abundant at higher elevations, especially in wet heath. Territory mapping in wet heath in the South Peak–Tafelkop region found ten pairs of adult buntings holding territories in 1990 and 1991. Given an area of 30 ha, this suggests a mean density of c.30 pairs/km<sup>2</sup>. In 2007, this had fallen to seven pairs, of which in only four were both birds in adult plumage. Two of the other three pairs comprised an immature male and an adult female, whilst the final pair was a juvenile (presumably male) and an adult female. Only two ‘mixed’ pairs comprising immature and adult birds were found in 1990, both at low elevation (Table 1). No bunting pairs were found in fern bush in 2007 (Table 1). The most dramatic decrease between 1990 and 2007 occurred at The Glen. Five pairs were found along the beach and adjacent valley up to the Northern Rockhopper Penguin *Eudyptes chrysocome* colony in 1990, but only one bird was seen in this area in 2007. The contrast between The Glen and Penguin Island, lying just offshore, was remarkable. We heard at least four singing males in c.1 ha on Penguin Island during a brief visit on 30 September 2007, whereas no singing was heard over a much larger area on the same morning at The Glen.

Surveys of upland areas in September 2007 counted 148 buntings. Of these, 20% were streaky juveniles, 8% were immatures in transitional plumage and 72% were adults. There was a tendency for the proportion of juveniles to be lower in areas where Tristan Albatross breeding success was low (Fig. 3), although this was only marginally significant ( $r_s=0.674$ ,  $F_{1,6}=4.98$ ,  $P=0.07$ ). No juveniles were observed in the north-west of the island, where buntings were scarce (only 18 buntings seen north-west of a line between Big Gulch and Barren Dome). Buntings also were scarce in this area in 1990, where the mean distance between pairs was estimated to be c.500 m, compared to 100–200 m in similar habitat in the southern highlands.

*Population size.*—A population of 1,500 pairs was estimated based on the density of pairs in 1990–91 (BirdLife International 2000). This assumed that South Peak–Tafelkop and Waterfall Camp were typical of favourable upland areas (25 km<sup>2</sup> with 40 pairs/km<sup>2</sup> = 1,000 pairs). Of the remaining 40 km<sup>2</sup>, half was assumed to be moderate habitat including cliffs suitable for breeding (20 km<sup>2</sup> with 20 pairs/km<sup>2</sup> = 400 pairs), and the other half was largely unsuitable, flat lowland (20 km<sup>2</sup> with 5 pairs/km<sup>2</sup> = 100 pairs). The density estimate of

TABLE 3

Foraging behaviour and diet (% of observations) of Gough Buntings *Rowettia goughensis* in lowland and highland habitats at Gough Island. Prey obtained from the first seven behaviours listed was mainly small invertebrates.

Character	Lowland (n=88)	Highland (n=446)
Digging and pulling up vegetation	21.6	37.7
Pulling apart rotten <i>Phylica arborea</i> wood	1.1	0.0
Gleaning epiphytes on <i>Phylica arborea</i>	20.5	0.0
Gleaning epiphytes on <i>Blechnum palmiforme</i>	10.2	0.4
Gleaning other vegetation	25.0	23.3
Entering seabird burrows	2.3	0.7
Hawking flying insects	1.1	0.4
Seeds of grasses and sedges	5.7	2.9
<i>Nertera depressa</i> fruits	13.6	32.7
<i>Empetrum rubrum</i> fruits	1.1	1.3
Scavenging muscle from bird carcasses	0.0	1.1

around 15–20 pairs/km<sup>2</sup> in Gonydale in 2000/01 is similar to that in the Tafelkop–South Peak area in 2007.

The population estimate requires revision in view of our recent density data. The southern highlands (15 km<sup>2</sup>) may support c.20 pairs/km<sup>2</sup>, but this is probably optimistic for the northern highlands (10 km<sup>2</sup>), where 5 pairs/km<sup>2</sup> is more likely. This yields a highland population of c.350 pairs. If the lowlands around the weather station and at The Glen are typical of the entire island, there are probably few buntings away from coastal cliffs over the remainder. Given a coastline of c.40 km, and using Cuthbert & Hilton's (2004) inter-nest distance on coastal cliffs of 600 m, this adds a further 65 nests. Offshore stacks may support relatively high densities of buntings, but they are small and unlikely to support more than a few tens of pairs. Thus the breeding population is probably 400–500 pairs. If 20% of birds are juveniles, and only half of the 8% immatures are paired, the total population in spring, in the pre-breeding season, is likely to be 1,050–1,350 birds.

*Morphology and moult.*—There was little difference between the sexes in terms of morphology, with males averaging 5% heavier and 1–3% larger in most linear measurements (Table 2). The mean size of juveniles, comprising both sexes, was intermediate between males and females, apart from the shorter tail length of juveniles. This is a function of the heavy wear exhibited in the tail-feathers of many juvenile buntings in spring. No birds were moulting flight-feathers; they presumably undergo a complete post-breeding moult in February–April like *Nesospiza* (PGR unpubl.).

*Foraging behaviour, diet and the abundance of invertebrates.*—Gough Buntings spent a large proportion of daylight hours foraging. Most food was obtained on or close to the ground, but birds in lowland habitats often gleaned prey from epiphytes on island trees and bogferns (Table 3). In the highlands, invertebrate prey was obtained by pulling up tufts of moss and other loose vegetation, or by gleaning insects from a wide variety of plants. Occasionally buntings would hawk airborne flies and moths, as well as scavenge flesh from seabird carcasses. Most invertebrate prey could not be identified, but large items included earthworms, caterpillars and moths. Bunting faeces contained the remains of flightless moths, spiders, and adult and larval beetles.



TABLE 4

Mean numbers of invertebrates per pitfall trap set at two sites in three habitats on Gough Island in December 2000.

Taxon	Coastal tussock (n=40)	Fern bush (n=36)	Wet heath (n=16*)
	mean ± SE	mean ± SE	mean ± SE
Diptera	16.4 ± 4.5	7.2 ± 1.4	0.2 ± 0.1
Coleoptera	4.7 ± 1.1	7.9 ± 4.9	0.3 ± 0.2
Lepidoptera	0.0 ± 0.0	0.0 ± 0.0	1.1 ± 0.3
Arachnida	1.0 ± 0.3	1.7 ± 0.4	0.6 ± 0.2
Acari	1.4 ± 0.5	2.5 ± 1.0	0.1 ± 0.1
Annelida	0.3 ± 0.2	0.2 ± 0.1	0.0 ± 0.0
Mollusca	0.1 ± 0.0	0.8 ± 0.2	0.1 ± 0.1
Isopoda	2.7 ± 0.6	6.0 ± 1.0	0.2 ± 0.1
Myriopoda	8.9 ± 4.2	92.9 ± 45.4	0.0 ± 0.0
Other insect orders	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1

\*Sample size in wet heath reduced because Subantarctic Skuas *Catharacta antarctica* dug up many traps.

The most conspicuous food taken in large quantities in the highlands was *Nertera depressa* fruit. All age classes ate these fruits, sometimes in large numbers. One adult male was observed to eat 37 fruits in two minutes. *Nertera* fruits were nibbled, apparently to extract the fleshy pulp, and the skin dropped. Each fruit contains two hard seeds, and these usually are discarded. Of 20 fruits discarded by a foraging bunting, 13 contained two seeds and the remainder one seed. Despite this, bunting faeces contained up to 20 *Nertera* seeds, and the gizzard of a juvenile contained 300 *Nertera* seeds. Buntings also ate seeds of a range of sedges (*Carex insularis*, *C. thoursii*, *Scirpus sulcatus*, *S. bicolor*, *Uncinia compacta*) and grasses, including native (*Agrostis*, *Calamagrostis* and *Deschampsia* spp.) and introduced species (*Holcus lanatus*, *Poa annua*).

Pitfall traps caught 5,752 invertebrates. Most (64%) were millipedes (Myriopoda), which apparently are not consumed by buntings. Of the remaining 2,051 invertebrates, 45% were flies (Diptera), 23% beetles (Coleoptera), 16% woodlice (Isopoda), 12% spiders and ticks (Arachnida and Acari), and smaller proportions of molluscs, earthworms and other insect orders. Apart from moths (Lepidoptera), invertebrate prey was more abundant in lowland habitats than in wet heath (Table 4).

*Breeding biology.*—Most breeders were in adult plumage, but some in transitional immature plumage were found, including a pair of immatures at Seal Beach in 1990. Breeding occurs from September to December. We found 12 nests with eggs or chicks in October, nine in November and nine in December, but breeding commences earlier at lower elevations. Voisin (1979) reported that chicks from a nest near sea level at the weather station fledged in early October, suggesting that the eggs were laid at the end of August. The earliest we saw fledged chicks was 18 October at c.200 m and 25 October at 500 m. The latest nests with eggs were found on 23 December at 450 m in Gonydale (one with two eggs, and another with one egg and one newly hatched chick).

Nests were open cups, constructed on or close to the ground, sheltered by overhanging vegetation or a rock. All nests in coastal tussock and fern bush (<450 m elevation) were sited on cliffs at least 4 m above ground (n=8). Most nests in upland areas also were on steep slopes (n=26), usually along stream banks, gulleys or on rock outcrops; only three were on relatively flat ground. The female constructed the nest, usually gathering material within 20 m of the nest site and flying with it to the nest. Initial material was coarse and large (up to

20 cm long), mainly grass and sedge leaves plus occasional fern fronds. Once the basic structure was assembled, it was lined with finer material, usually *Scirpus bicolor* stems. Completed nests measured  $148 \pm 16$  mm (SD, range 130–190 mm) across, with a cup  $92 \pm 12$  mm (75–100 mm) across and  $55 \pm 15$  mm (35–90 mm) deep ( $n=14$ ).

The pale blue eggs, variably speckled grey-brown, with markings usually concentrated at the blunt end, were laid 1–2 days apart. Clutch size was  $2.0 \pm 0.25$  eggs (1–3;  $n=33$  including data from Voisin 1979, Williams & Imber 1982). The mean size of 36 eggs was  $27.7 \pm 1.2$  mm (25.5–30.2)  $\times$   $19.4 \pm 0.5$  mm (18.3–20.4) (including the two eggs reported by Voisin 1979). Incubation was by the female alone. Duration of the

incubation period is unknown. The male assisted by feeding the female on average every  $22.7 \pm 9.5$  minutes (range 4–50 minutes,  $n=64$  inter-visit intervals), calling to her, whereupon she left the nest to be fed. She also foraged for herself, leaving the eggs unattended for on average  $6.3 \pm 5.5$  minutes (1–28 minutes,  $n=73$  incubation absences). After hatching, the chicks were brooded by the female for several days. Brood shifts averaged shorter ( $10.4 \pm 7.7$  minutes, 1–31 minutes,  $n=29$ ) than incubation shifts ( $15.3 \pm 9.7$  minutes, 2–44 minutes,  $n=62$ ), but periods away from the nest were only slightly longer ( $8.7 \pm 5.9$  minutes, 1–24 minutes,  $n=37$ ). The male continued to feed the female during brooding, but the interval between feeds increased (average  $32.7 \pm 15.4$  minutes, 10–69 minutes,  $n=20$ ). The male did not feed the chicks directly while the female was brooding, but once she started to spend more time foraging, he delivered food directly. Large chicks (>10 days old) were fed every  $16.5 \pm 11.4$  minutes (1–55 minutes,  $n=83$ ). Chicks fledged after *c.* 20 days, but remained concealed in cover for another week or so. Thereafter, they remained on the natal territory, and were fed by the adults at least occasionally, for several weeks.

The only breeding success data are those reported by Cuthbert & Hilton (2004) from Gonydale. Overall, 52% of nests fledged at least one chick, and given a mean 1.67 fledglings per successful nest, this results in a mean of 0.87 fledglings per breeding attempt. There is no evidence that pairs raise more than one brood per season, but at least one pair re-laid 23 days after the loss of its first clutch. The second clutch also failed.

## Discussion

Numbers of Gough Buntings have decreased since the first records were made of the species in the late 19th century, and they continue to do so. Most significantly, territory mapping in 2007 suggests that the population has roughly halved within the last two decades. The increasing occurrence of birds breeding in immature plumage and holding territories in juvenile plumage also is indicative of a decreasing population. Gough Buntings are strongly territorial, with adults chasing young from their territories (Holdgate 1958; pers. obs.). That juveniles and immatures now hold territories suggests that there are more vacant territories than was the case even a decade or so ago. Wilkins (1923) reported

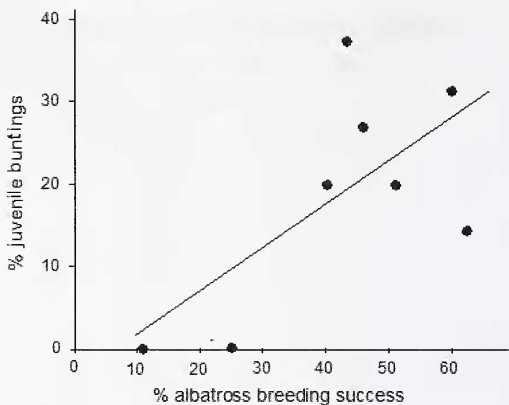


Figure 3. Correlation ( $r^2=0.45$ ,  $P<0.07$ ) between the proportion of juvenile Gough Buntings *Rowettia goughensis* and Tristan Albatross *Diomedea dabbenena* breeding success in different highland areas in 2007.

that most buntings occurred in flocks of up to seven; this is no longer the case. Birds are typically solitary or in pairs; one group of four seen in September 2007 was exceptional.

Recent decreases have been most marked at lower elevations. Buntings were still fairly common in fern bush around the weather station in the 1970s (Voisin 1979, Clancey 1981), but were virtually absent by 1990. They disappeared from mid-elevation cliffs inland of the weather station between 1990 and 2007, and have become much less abundant at The Glen over this period. This apparently continues a long-term trend of a decrease in numbers at low elevation. Cuthbert & Hilton (2004) considered the possibility that the greater abundance of buntings at higher elevations may simply reflect the pre-mouse distribution of the birds, but Wilkins (1923) specifically mentioned that buntings were more common along the coast than inland. *Nesospiza* buntings also are more abundant at low elevations on Inaccessible Island, Tristan da Cunha (PGR unpubl.).

Two findings support the hypothesis that mice are responsible for the decrease in bunting numbers. First is the abundance of buntings on Penguin Island. Landing on this apparently mouse-free islet was reminiscent of landing on Inaccessible or Nightingale in the Tristan group, both of which are free of introduced rodents and support high densities of buntings. The density of buntings on Gough is almost two orders of magnitude lower than that in coastal tussock on Inaccessible. Second is the paucity of juveniles in the population. Wilkins (1923) suggested that streaky juveniles occurred in equal numbers to adults in 1922, and Elliott (1957) reported that juveniles were rather more common than adults in 1952. This contrasts with the situation in 2007, when only 20% of birds were juveniles. The low proportion of juveniles suggests that recruitment is insufficient to maintain the population.

Mice could affect buntings either through competition for food or predation of eggs and chicks (Cuthbert & Hilton 2004). These are not mutually exclusive impacts, but their relative importance can be assessed by examining the distribution of buntings in relation to the availability of their food. If competition is the main factor, we would expect buntings to persist in areas where their food is most abundant. Our pitfall trap data refute this, suggesting that food is not preventing Gough Buntings from occurring in the coastal lowlands on Gough. Predation is thus probably the main factor driving the population decline, which supports the finding that artificial bunting nests suffered much greater predation by mice in the lowlands than the highlands (Cuthbert & Hilton 2004). It is perhaps surprising that juvenile buntings do not descend to the lowlands to forage, especially in the face of aggression by territory holders in the highlands. This may be a consequence of their limited dispersal range, or possibly other issues, such as disturbance by mice while roosting in the lowlands. The limited movements exhibited by individually marked buntings accord with previous observations of banded birds at The Glen (Holdgate 1958).

The breeding biology of Gough Buntings is similar to that of *Nesospiza* buntings on Inaccessible Island (Fraser & Briggs 1992, Ryan & Moloney 2002). The main difference is the selection of nest sites. Most *Nesospiza* nests are on the ground in fairly flat terrain (Ryan & Moloney 2002), whereas Gough Buntings typically nest on cliffs or steep slopes. There are no historical records to test whether this difference is an adaptive response to reduce the risk of mouse predation, or simply a function of the heavier rainfall on Gough. However, it is certain that buntings no longer breed in fern bush around the weather station where the first nest was described (Voisin 1979). Also, the prevalence of cliff nesting is greatest at low elevations, where mouse densities are greater, and predation of artificial nests much greater (Cuthbert & Hilton 2004), suggesting that mice are indeed responsible for buntings avoiding nesting in easily accessible sites on Gough (or the selective removal of pairs that nest in readily accessible sites). The rate of delivery of food to the nest was similar to that of Tristan Buntings *N. acunhae* at Inaccessible (Fraser & Briggs 1992), both during incubation ( $2.6 \text{ h}^{-1}$  at



Gough, 2.7 h<sup>-1</sup> at Inaccessible) and when provisioning chicks (3.6 h<sup>-1</sup> at Gough, 5.7 h<sup>-1</sup> at Inaccessible). This suggests that, at least in Gonydale, Gough Buntings did not struggle to obtain invertebrate food. However, competition for food between mice and buntings is likely to be most severe in winter, when mouse populations decrease dramatically due to starvation (Wanless 2007; RJC unpubl.). Competition for food in winter is likely to result in reduced annual survival, especially among juvenile buntings. Unfortunately we lack sufficient data to test this hypothesis.

Gough Bunting breeding success in Gonydale in 2000/01 was not particularly low. The estimate of 0.87 fledglings per breeding attempt compares favourably with data for *Nesospiza* buntings at Inaccessible (0.82 fledglings per attempt,  $n=139$  nests; PGR unpubl.). However, breeding success in Gonydale may be atypical, given that Tristan Albatrosses consistently have better breeding success here than anywhere else on the island (Cuthbert *et al.* 2004, Wanless 2007). The reason for spatial heterogeneity in mouse impacts across Gough is obscure, and it is not immediately evident why there should be a link between predation on albatross chicks in winter and that on bunting eggs and chicks in early summer. One possibility is that higher winter survival of albatross-eating mice enhances local mouse populations, increasing pressure on nesting buntings in spring. The low proportion of juvenile buntings elsewhere on the island, especially in the north-west, where albatross breeding success is invariably very poor, suggests that bunting breeding success probably is lower in other areas than that recorded at Gonydale. Climate change may exacerbate this problem, as warmer winters will presumably permit more mice to survive.

We lack sufficient data on survival to construct a robust demographic model for the bunting. It is unclear when mice arrived on the island (although it was presumably between 1800 and 1888), or when they started to impact the bunting. It may be a relatively recent phenomenon, because the climate at Gough has warmed over the last 40 years (Jones *et al.* 2003). Irrespective of the considerable uncertainty regarding this system, it seems clear that the Gough Bunting population is decreasing, and that its threat status should be revised. With a population of c.1,000 mature individuals confined to a single site of only 65 km<sup>2</sup>, and having experienced a population decrease of c.50% over the last three generations (assuming the mean age of breeding adults is 5–6 years), it qualifies as Critically Endangered under IUCN Criterion B1 a+b (ii, v), a recommendation accepted by BirdLife's assessment panel (S. Butchart *in litt.* 2008). The plight of this distinctive endemic species provides further, urgent impetus for calls to eradicate mice from Gough ([www.rspb.org.uk/ourwork/conservation/projects/tristandacunha/index.asp](http://www.rspb.org.uk/ourwork/conservation/projects/tristandacunha/index.asp)).

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- Addresses: Peter G. Ryan, Percy FitzPatrick Institute DST/NRF Centre of Excellence, University of Cape Town, Rondebosch 7701, South Africa, e-mail: peter.ryan@uct.ac.za. Richard J. Cuthbert, Royal Society for the Protection of Birds, The Lodge, Sandy, SG19 2DL, UK, e-mail: Richard.Cuthbert@rspb.org.uk